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INTRODUCTION

An important distinction between Order Point systems and Material Requirements Planning systems lies in the fact that the order point/order quantity approach is ***part-based*** whereas MRP is ***product-oriented.*** Order Point views each inventory item independently of all the others, whereas MRP looks at the product and the relationships of its components, using bills of material as the basis for planning.

MRP puts the bill of material to a whole new use. Under MRP, the bill acquires a new function, in addition to serving as part of the product specs. It becomes a framework on which the whole planning system hangs.

Often, however, the bill of material furnished by the engineering department is not necessarily ***usable*** for material requirements planning. As a key input to an MRP system, the bill of material must be accurate and up-to-date if MRP outputs are to be valid. But in addition it must be unambiguous and so structured as to ***lend*** itself to MRP. The mere existence of a bill of material is no guarantee that MRP will actually work.

To understand the reason for this, we must remember that the bill of material is basically an engineering document. Historically, the function of the bill of material has been to define the product from the design point of view and from the design point of view only. But now, because we want to use the bill of material for purposes of material planning, we must re-define the product from the manufacturing and planning point of view. Proper product definition is crucial to a planning system such as MRP, which directly depends on it—***unlike*** an order point system.

People usually think of bills of material and of MRP as being applicable only in hard goods manufacturing. But businesses that ***mix*** component materials, ***sew*** them together, ***package*** them, etc., can also use material requirements planning to advantage. Companies in the garment industry, pharmaceutical houses, batch chemical manufacturers, and others, all have bills of material except they call them by different names—material lists, formulations, specifications, etc.

With MRP, the prime input to the whole system is the master production schedule. The product must be defined in such a way as to make it possible to put a valid master schedule together in terms of bill of material numbers; i.e., assembly numbers. If the overall plan of production—and that is what the master schedule is—cannot be stated in terms of bills of material, it is not possible to do material requirements planning successfully.

The master schedule and the structure of the bill of material must be thought of together, when an MRP system is being developed. The bills of material and the master schedule must ***fit together*** like lock and key. If these are not compatible, nothing turns. Neither is there any guarantee that an MRP system can function properly just because the bill may already have been organized and loaded onto a computer file under a ***Bill of Material Processor*** program. This type of software will load practically anything onto a disc file, including straight engineering parts lists—

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which are not much good for purposes of material requirements planning. The functions of a bill processor are merely to organize, maintain, and retrieve bill of material data. A Bill of Material Processor is not designed to ***structure*** the bill. It assumes that the bill is already properly structured to serve the user's needs.

The intent of the discussion that follows is to clarify the subject of bill of material ***structuring,*** so that it will not be confused with bill of material ***file organization*** under a bill processor.

In most instances, companies planning to implement MRP will be wise to review their bills of material, to determine whether certain changes in the structure of this file data may have to be made and of what kind. In reviewing the bill for this purpose, the following seven-point checklist will help in spotting its structural deficiencies:

1. ***The bill should lend itself to the forecasting of optional product features.*** This capability is essential for purposes of material requirements planning.
2. ***The bill should permit the master schedule to be stated in the fewest possible number of end items.*** These end items will be products or major assemblies, as the case may be, but in either case they must be stated in terms of bill of material numbers.
3. ***The bill should lend itself to the planning of subassembly priorities.*** Orders for subassemblies have to be released at the right time and with valid due dates.
4. ***The bill should permit easy order entry.*** It should be possible to take a customer order that describes the product either in terms of a model number or as a configuration of optional features and translate it into the language that the MRP system understands: bill of material numbers.
5. ***The bill should be usable for purposes of final assembly scheduling.*** Apart from MRP, the final assembly scheduling system needs to know, specifically, which assemblies (assembly numbers) are required to build individual units of the end product.
6. ***The bill should provide the basis for product costing.***
7. ***The bill should lend itself to efficient computer file storage and file maintenance.***

When, in a given case, these yardsticks are applied to the existing bill of material, it will usually be found that some, but not all, of the above requirements can be satisfied. If that is the case, changes in bill of material structure are called for. This can and should be done. While the bill still must serve its primary purpose of providing product specifications, it should not be regarded as a sacrosanct document that must not be tampered with. The bill may have to be modified, or ***restructured***, as required for purposes of material requirements planning. This can be done without affecting the integrity of the specs.

The severity of the bill of material structure problem varies from company to company, depending on the complexity of product and nature of the business. The term "bill of material structuring" covers a variety of ***types*** of changes to the bill, and several different techniques for effecting these changes.

The topics that make up the subject of bill of material structuring, as reviewed in this article, can be categorized as follows:

1. ***Assignment of identities***
   (a) Elimination of ambiguity
   (b) Levels of manufacture

2. ***Modular bill of material***
   (a) Disentangling product option combinations
   (b) Segregating common from unique parts.
3. ***Pseudo-bills of material***

IDENTIFICATION OF MATERIALS AND THEIR RELATIONSHIPS

There are several principles involved here. First, the requirement that each individual item of inventory covered by the MRP system be uniquely identified. This includes raw materials and subassemblies.

The assignment of subassembly identities tends to be somewhat arbitrary. Between the design engineer. the industrial engineer, the cost accountant and the inventory planner, each might prefer to assign them differently. The question is: When do unique subassembly numbers have to be assigned? In reality, it is not the design of the product but the way it is being manufactured; i.e., assembled, that dictates the assignment of subassembly identities.

The unit of work, or task, is the key here. If a number of components are assembled at a bench and then are forwarded as a completed task to storage or to another bench for further assembly, a subassembly number is required so that orders for these subassemblies can be generated and their priorities planned. An MRP system will do this, but only for items with individual identities.

Some engineering departments are stingy in assigning new part numbers and we often see the classic example of this in a raw casting that has the same part number as the finished casting. This may suit the engineer, but it is difficult to see how an automated inventory system such as MRP is supposed to distinguish between the two types of items that must be planned and controlled separately.

The second requirement is that an identifying number define the ***contents*** of the item uniquely, unambiguously. Thus the same subassembly number must not be used to define two or more different sets of components. This sometimes happens when the original design of a product subsequently becomes subject to variation. Instead of creating a new bill with its own unique identity, the old one is specified with instructions to substitute, remove and add certain components. This shortcut method, called "add and delete," represents a vulnerable procedure, undesirable for MRP. We will come back to it in a later example.

The third requirement is that the bill of material should reflect the way material flows in and out of stock. "Stock" here does not necessarily mean "stockroom" but rather a ***state of completion.*** Thus when a piece part is finished or a subassembly is completed, it is considered to be "on hand"; i.e., in stock, until withdrawn and associated with an order for a higher level item as its component. An MRP system is constructed in such a way that it assumes that each inventory item flows into and out of stock at its respective level in the product structure. MRP also assumes that the bill of material accurately reflects this flow.

Thus the bill of material is expected to specify not only the ***composition*** of a product but also the ***process stages*** in that product's manufacture. The bill must define the product structure, in terms of so-called ***levels of manufacture,*** each of which represents the completion of a step in the buildup of the product.

A schematic representation of product structure is shown in Figure 1. The structure defines the relationship among the various items that make up the product in terms of levels, as well as the parent item/component item relationships. These things are vital for material requirements planning because they establish, in conjunction with lead times, the precise ***timing*** of requirements, order releases and order priorities.

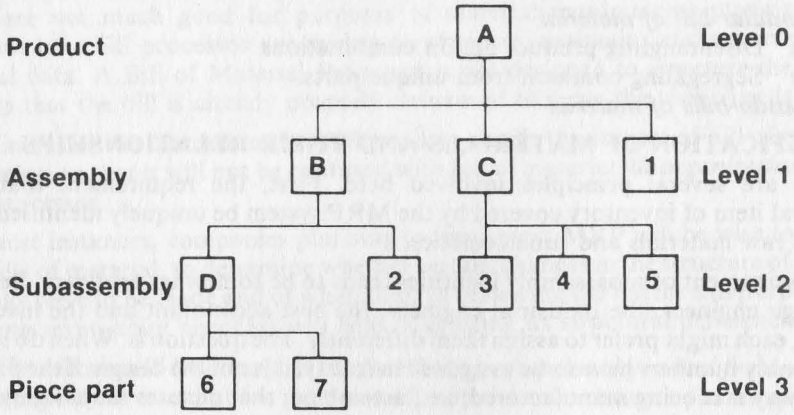

Figure 1.

The product represented by Figure 1 has four levels of manufacture. The end product is designated, by convention, as being at level zero, its immediate components as being at level one, etc. The parent/component relationships depicted in the example indicate that "A" is the parent of component "C" (also of "B" and "1"). Item "C," in turn, is the parent of component "3," etc. Thus "A" is the only item that is not also a component. Items "B," "C" and "D" are both parents (of their components at the next lower level) and components (of their parent items at the next higher level). Items "1" through "7" are components but never parents.

This would be true if all of the piece parts were purchased. If item "6," however, is manufactured from raw material "X," then it becomes a parent in relationship to this component material. Thus the distinction between parent item and component item appears not only in assembly but also in the conversion of material for a single part from one stage of manufacture to another.

This also applies to semi-finished items that are stocked (in the sense described earlier) and that are to be controlled by the MRP system. The raw material, the semi-finished item and the finished item must be uniquely identified; i.e., must have different part numbers.

People are sometimes reluctant to assign different identities to semi-finished and finished items, where the conversion to the finished stage is of minor nature. A good example is a die casting that is machined and then painted one of four different colors, as shown in Figure 2. The four varieties of painted casting will have to be assigned separate identities if they are to be ordered, and their order priorities planned, by the MRP system.

This is an example of a situation where item identity (of the painted casting) would normally not exist, but would have to be established pre-requisite to MRP, because otherwise such items would fall outside the scope of the system and loss of control would result.

Another example of an item identity problem that is almost the opposite is the transient subassembly, sometimes called a "blow-through" or "phantom." Assemblies of this type never see a stockroom, because they are immediately consumed in the assembly of their parent items. An example of this is a subassembly built on a feeder line that flows directly into the main assembly line. Here the subassembly normally carries a separate identity. Because it is recognized in the bill of material, the MRP system would treat it the same as any other subassembly.

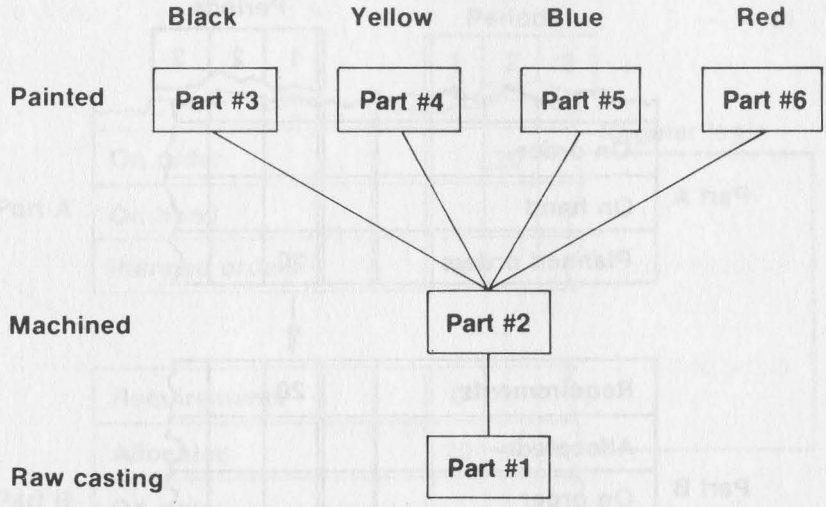

Figure 2.

This may be undesirable, because if this kind of item is to be planned under an MRP system, we must remember that the logic of MRP assumes that each component item goes in and out of stock. That is the way the basic time-phased record is designed and updated. So the question arises as to how to handle such subassemblies within an MRP system. MRP users have worked out techniques to deal with this situation. People often wonder whether this type of assembly should be identified in the bill at all. The phantom does not require separate identity in the bill of material, provided there is never:

1. An over-run
2. A service part demand
3. A customer return.

Otherwise, it must be separately identified in the bill and item records (stock status) must be maintained. This is so because over-runs, service demand, and returns create a need to stock material, and to control it. But then the MRP user would have to report all transactions for the phantom subassemblies, so that the system can post these and keep the records up-to-date. This seems like unnecessary effort and paperwork in the case of order releases and order completions.

Fortunately, there is no need to do this. A technique called the "phantom bill" eliminates the need for posting such transactions for these items. (This technique is used, for instance, by the Black & Decker Manufacturing Company, a skilled MRP user.) Using this technique, it is possible to have your cake and eat it. While transactions of the type mentioned do not have to be reported and posted, the MRP system will pick up and use any phantom items that may happen to be on hand. Service part requirements can also be entered into the record and will be correctly handled by the system. But otherwise MRP will, in effect, bypass the phantom item's record and go from its parent item to its components directly.

To describe the application of this technique, let's assume that assembly "A" has a transient subassembly "B" as one of its components, and part "C" is a component of "B." Thus, for purposes of illustration, item "B," the phantom, is envisioned as being sandwiched between "A," its parent, and "C,' its component.

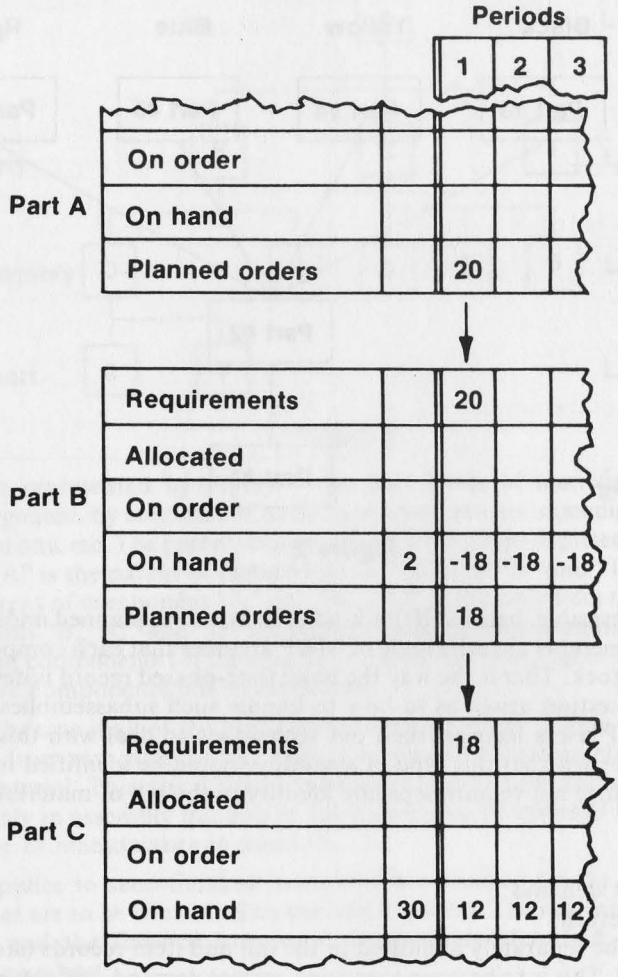

Figure 3.

To implement this technique, the phantom item is treated as follows:

1. Lead time is specified as zero.
2. Lot sizing is discrete (lot for lot).
3. The bill of material (or the item record) is coded, so that the system can recognize that it is a phantom and apply special treatment.

he special treatment referred to above means departing from regular procedure, or ecord update logic, when processing the phantom record. The difference between the rocedures can best be described through examples.

In Figure 3, inventory status data for items "A" (top), "B" (middle), and "C" bottom) are shown. Note that the zero lead time offset on the item in the middle places ne planned order release for 18 pieces in the same period as the net requirement. This, turn, corresponds to the requirement for 18 "C"s in the same period.

Following the release of the planned order for "A," the update procedure for item ord "B" will vary, depending on whether it is coded as a phantom. In the absence of

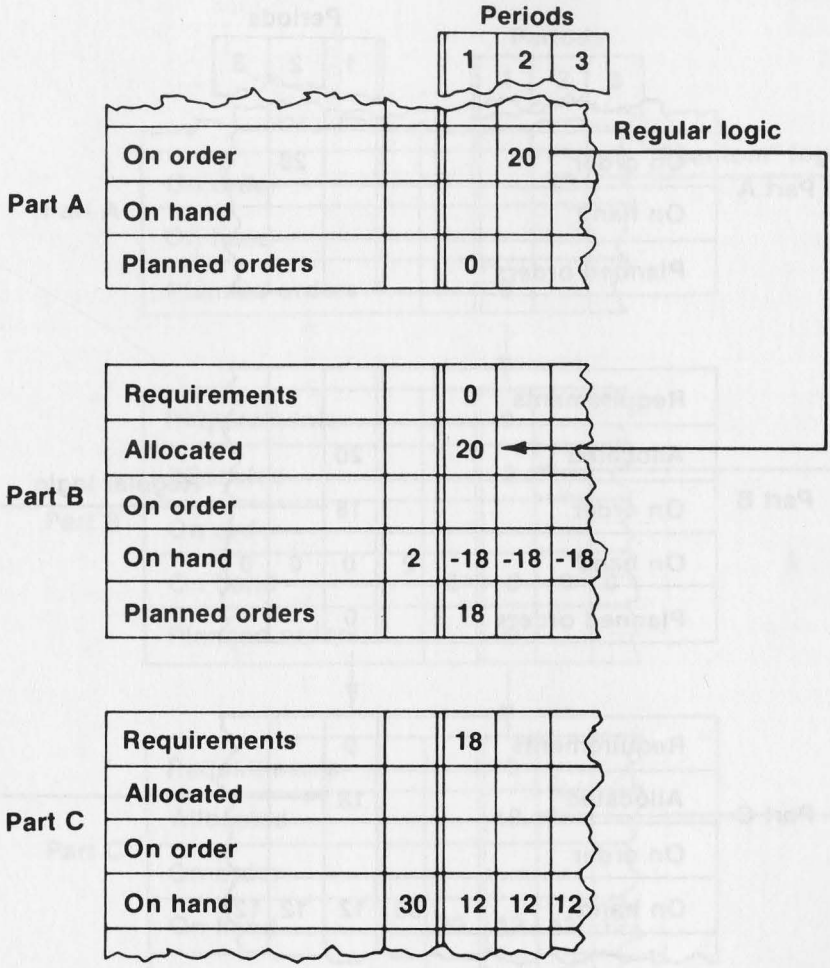

Figure 4.

such a code, regular logic applies. The regularly updated records of "A" and "B" are shown in Figure 4. Record "C" continues unchanged. Following the release of the planned order for "B," item record "C" is updated, as shown in Figure 5.

Had item "B" been coded as a phantom, all three records would have been updated in one step, as shown in Figure 6, as a result of the planned order release of item "A." Note that the release of planned order "A," which normally would reduce only the corresponding requirement "B" (as in Figure 4), in this case reduces also the requirement for "C," ***as though "C" were a direct component of "A."***

Note also that the two pieces of "B" in stock (perhaps a return from a previous overrun) are applied to the requirement for "A," and that the allocation has been ***distributed*** between "B" and "C." Upon closer examination of these examples it will be

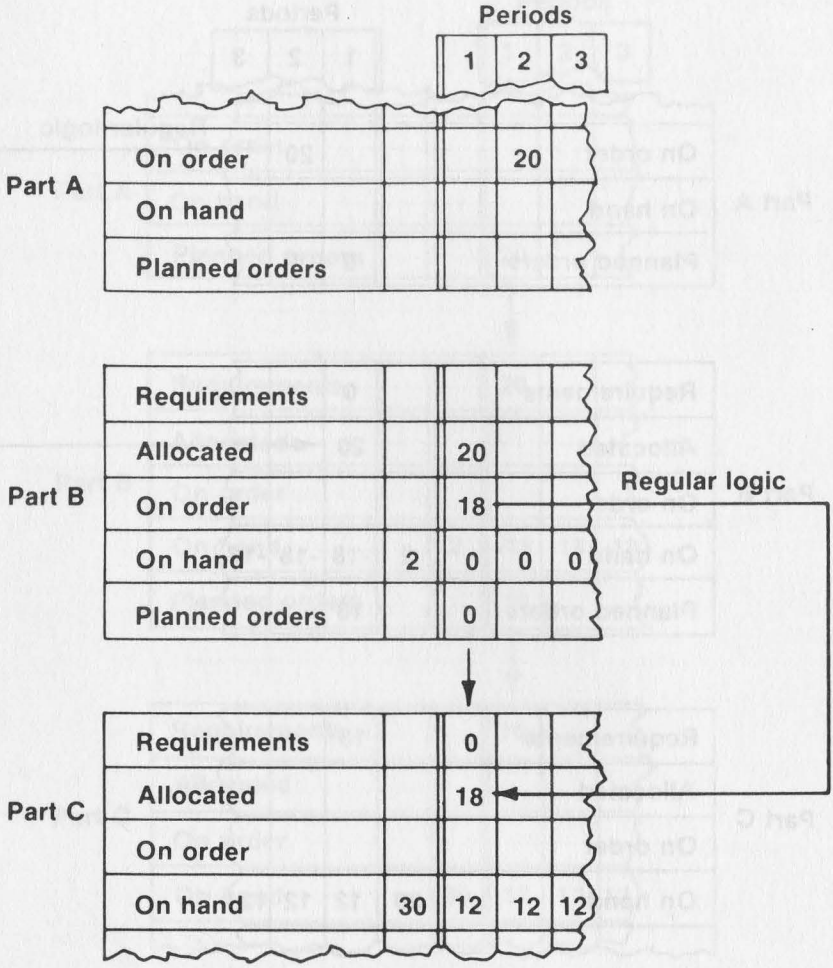

Figure 5.

seen that the phantom logic is nothing more than a different treatment of ***allocation.*** (Zero lead time and discrete lot-sizing are assumed. These can, however, be specified for non-phantom subassemblies also.) Once this step is carried out, regular logic applies, causing the records to be updated and their data aligned in the correct manner.

The phantom bill technique, as described above, applies to MRP systems of the Net Change type. In conventional regenerative MRP systems the question of posting or not posting transactions to the phantom record is not crucial, because a planned order release does not update component requirements data. Hence, the problem of rebalancing or realigning the planned order and requirements data of the three records does not arise. Following the planned order release of the phantom's parent, the next regeneration will wash out both the requirement and the planned order release for the phantom item.

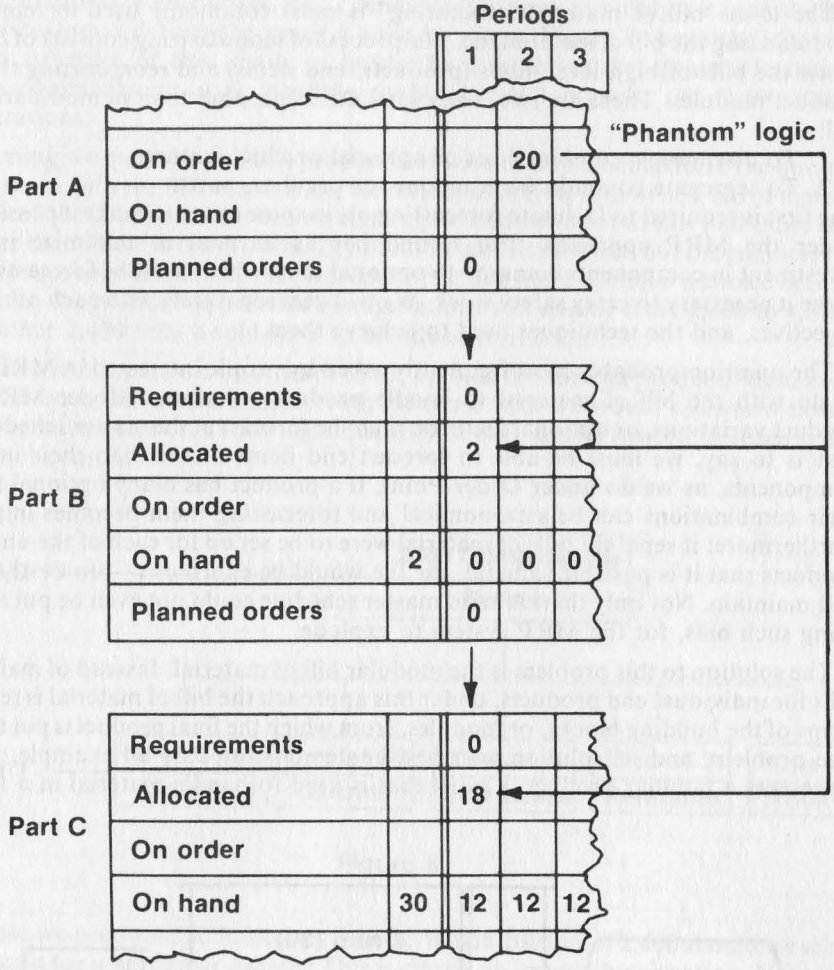

Figure 6.

The objective of not having to post phantom transactions still remains, however, and it can be achieved by, again, setting lead time to zero, specifying discrete lot-sizing, and coding the phantom item so that notices for planned order releases are either suppressed or flagged to be disregarded. The MRP system will function correctly.

The problem then becomes one of component requisitioning (for the phantom parent order) and it must be solved by modifying the requisition generating procedure. When some phantom items are on hand, ***two*** requisitions will have to be generated:

1. One for the quantity of the phantom on hand
2. One for the balance of the order; for the phantom's components.

In the Figure 6 example, these quantities are 2 and 18, respectively.

MODULAR BILLS OF MATERIAL

The term "bill of material structuring" is most commonly used in reference to modularizing the bill of material file. The process of modularizing consists of ***breaking down*** the bills of high-level items (products, end items) and ***reorganizing*** them into product modules. There are two, somewhat different, objectives in modularizing the bill:

1. To disentangle combinations of optional product features
2. To segregate common from unique, or peculiar, parts.

The first is required to facilitate forecasting or, in some cases, to make it possible at all under the MRP approach. The second has as its goal to minimize inventory investment in components common to optional units which must be forecast and thus make it necessary to carry safety stock. We will deal separately with each of these two objectives, and the techniques used to achieve them.

The question probably most frequently asked by people interested in MRP is what to do with the bill of material to handle product variations. Under MRP, these product variations, or optional features, must be forecast at the master schedule level, that is to say, we must be able to forecast end items rather than their individual components, as we do under Order Point. If a product has many optional features, their combinations can be astronomical and forecasting them becomes impossible. Furthermore, if separate bills of material were to be set up for each of the unique end products that it is possible to build, the file would be enormous—too costly to store and maintain. Not only that. A valid master schedule could not even be put together, using such bills, for the MRP system to explode.

The solution to this problem is the modular bill of material. Instead of maintaining bills for individual end products, under this approach the bill of material is restated in terms of the building blocks, or modules, from which the final product is put together. The problem, and its solution, can best be demonstrated by an example. Figure 7 represents a familiar product, a hoist that is used to handle material in a factory.

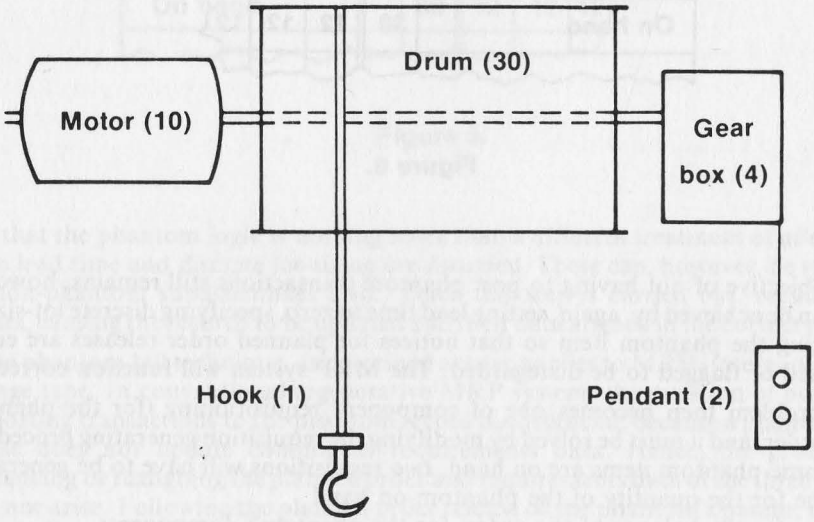

Figure 7.

The hoist manufacturer offers his customers a number of options, in this case 10 motors, 30 drums, 4 gear boxes, and 2 pendants (the hook assembly is standard), from which a customer defines the specific hoist he wants. Figure 8 shows the schematic product structure of this family of hoists. By assembling the optional features in various combinations, it is possible to build 2,400 models; i.e., 2,400 unique configurations.

Assuming we manufacture this product and wish to implement MRP, the question is what to do with the bill of material. We can see clearly how to write a bill of material for each of the 2,400 models, but we certainly would not want to carry all those bills. Consider this: There is only one variety of hook on this product, but the engineers are probably working on that. If they introduce just one more option—a choice between two hooks, the number of possible configurations will ***double*** from 2,400 to 4,800—and another 2,400 bills would have to be added to the file.

That is one reason we do not want to set up bills for the end products themselves. But aside from this consideration, with all those bills we would not know how to develop a master schedule showing a quantity of each model needed in specific time periods.

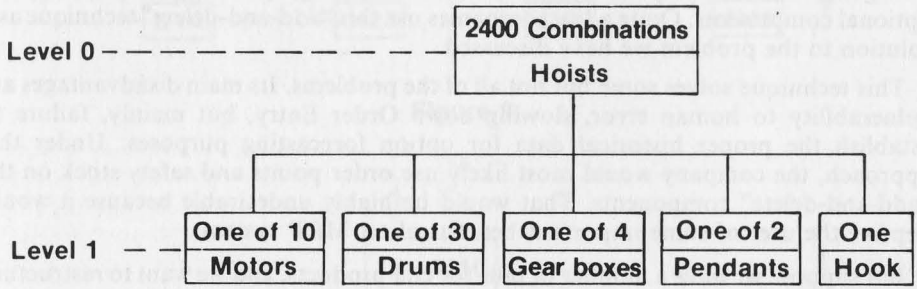

Figure 8.

Suppose we produce 100 hoists per month. Which 100 out of 2,400 should we select as a forecast for a particular month? This is clearly an impossible situation. Note that ***volume*** is part of the problem here. A product family with 100 models is a problem if volume is 20 per month. If volume were 10,000 per month, the forecasting problem would not be nearly as serious.

The solution here is to forecast each of the highest-level ***components*** (i.e., major assembly units) separately, and not to try to forecast the end products at all. That way, we would forecast each of the ten different motor variations, the thirty drum sizes, the four types of gear box, and the two types of pendant.

Specifically, since we only have one hook assembly and want to make 100 hoists during a month, we will need 100 hooks. This quantity would appear in the master schedule, and a bill of material for this "module" would be required to match the schedule. But we have two types of pendant. From previous sales of this product we know that, let us say, 75 percent of the orders call for type "A" and 25 percent for type "B." Applying these percentages to the pendant option, we could schedule seventy-five "As" and twenty-five "Bs." But here we would probably want some safety stock, because the batch of 100 customer orders in any one month is unlikely to break down exactly 75 and 25 percent.

The proper way to handle safety stock under material requirements planning is to plan it at the master schedule level. Thus, instead of scheduling 75 and 25 percent of the pendants we would deliberately overplan and put, let us say, 90 and 30 into the master schedule. (This would not be done in every period; the unused safety stock is rolled forward.) The same approach would be followed for the motor option, the drum option and the gear box option.

Each of the options, or ***modules,*** would have to have a bill of material for use by the MRP system. Under this approach, the total number of bills of material—and the things to forecast—would be as follows:

Motors	10	Pendants	2
Drums	30	Hook	1
Gear Boxes	4	Total	47

This total of 47 compares with 2,400 if each product model had a bill of its own. If the engineers add a second variety of hook, this would only add one more bill to the 47, instead of doubling the file.

At this point, the reader may be wondering how this type of problem is being handled in a real-life situation, if the manufacturer ***does not*** have the bills set up in modular form. Chances are that there would be ***several bills, for some of*** the 2,400 configurations, and they would be used for everything by adding and subtracting optional components. Quite a few companies use this "add-and-delete" technique as a solution to the problem we have discussed.

This technique solves some but not all of the problems. Its main disadvantages are vulnerability to human error, slowing down Order Entry, but mainly, failure to establish the proper historical data for option forecasting purposes. Under this approach, the company would most likely use order points and safety stock on the "add-and-delete" components. That would be highly undesirable because it would deprive the user of some important benefits of an MRP system.

But suppose we ***have*** a number of bills for end products, and we want to restructure them in a modular fashion, so we can get away from adding and deleting. How do we go about such restructuring, specifically? We will demonstrate this on the next example. For this purpose, we have to scale down the previous example somewhat, so the solution can be seen clearly. Let us assume that the product has only ***two*** optional features, the motor and the drum, each with only two choices. The customer can then select between motor #1 and motor #2, and between drum "A" and drum "B."

Figure 9 represents the four bills of material: the first combines motor #1 with drum "A,"the second one, motor #1 with drum "B," etc. In the product structure, the end product (model) numbers, 12-4010 etc., are considered to be on level zero. The level-one components, A13, C41, etc., may represent assemblies, but their components are not shown on the chart, so as not to make it too busy.

To restructure these bills into modules, we break them down, analyze and compare the use of level-1 items, and group them by use. For example, we see that the first component in the first bill, A13, is common to all products, and assign it to the ***Common*** group. The next item, C41, is found in #1-A and #1-B combinations but not in #2-A and #2-B, which indicates that it is ***unique to motor option*** #1. The item that follows, L40, is ***used only with drum option "A."*** The remaining component items are similarly examined and assigned to groups. The result is shown in Figure 10.

Note, in Figure 10, that the last level-1 component item, D14, does not fit into any of the groupings. When all of the bills are broken down this way and their level-1 components are grouped by option, items D14, H23, J39, and N44 in our example

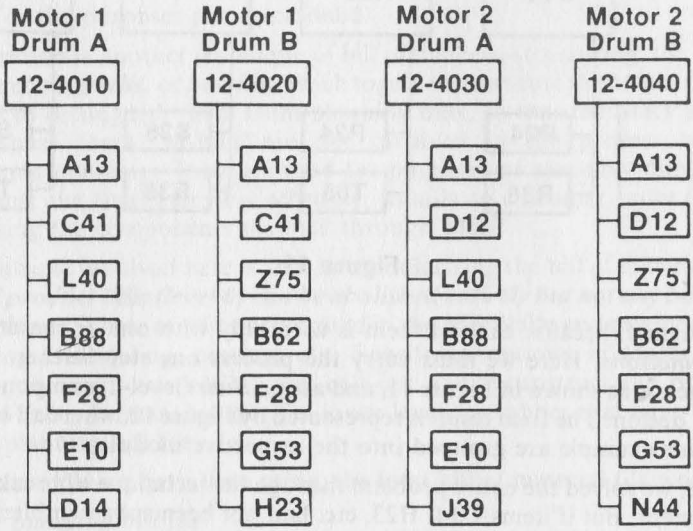

Figure 9.

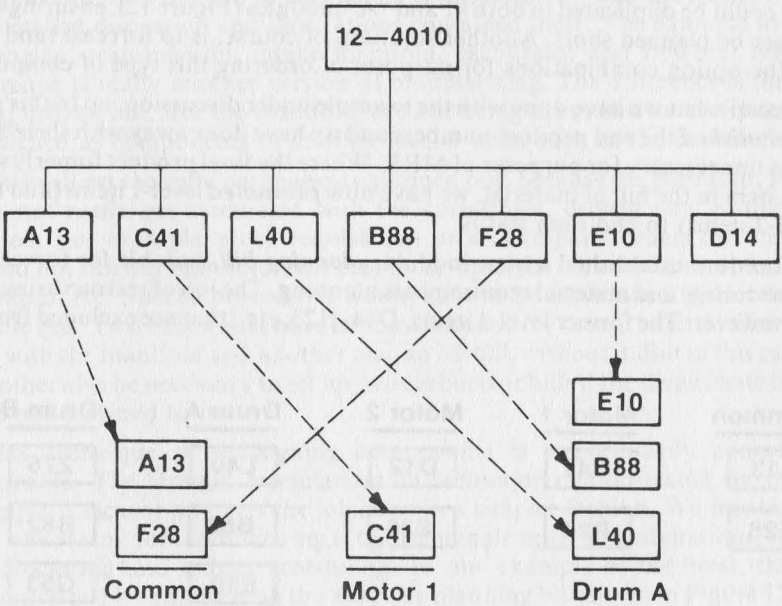

Figure 10.

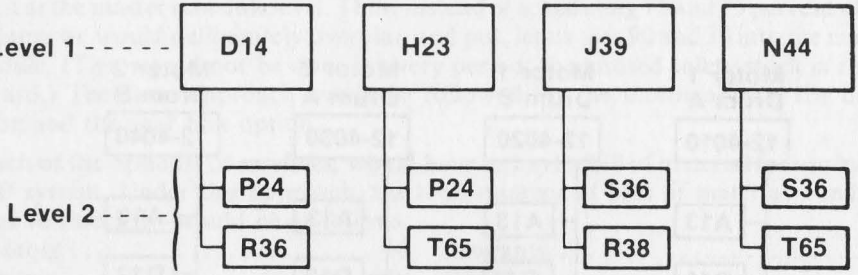

Figure 11.

remain unassigned, because each of them is used only with one or the other of the option ***combinations.*** Here we must carry the process one step further; i.e., break down these items, as shown in Figure 11, and assign ***their*** (level-2) components to the groupings by option. The final result is represented by Figure 12, where all of the items involved in our example are grouped into the respective modules.

In our case, we solved the entire problem through the technique of breakdown and group assignment. But if items D14, H23, etc. had not been subassemblies but piece parts, we would not have been able to break them down. In a case like that, the part that is used only with a certain combination of options should, if possible, be redesigned, particularly if it is an expensive item.

Low-cost items of this type need not be re-engineered, because we can afford to overplan them and carry some excess inventory. In the modularizing process, such parts can simply be assigned to more than one grouping. For example, item D14 (Figure 9) could be duplicated in both #1 and "A" modules (Figure 12), ensuring that it would never be planned short. Another solution, of course, is to forecast (and over-forecast) the option combinations for purposes of ordering this type of component.

Let us recap what we have done with the example under discussion, up to this point. We have ***abolished*** the end product numbers and we have done away with their bills of material as unnecessary for purposes of MRP. Where the final product fomerly served as the end item in the bill of material, we have now ***promoted*** level-1 items (and in one case, level-2 items) to end item status.

This procedure established a new, modular ***planning bill,*** suitable for forecasting, master scheduling, and material requirements planning. The job of restructuring is not finished, however. The former level-1 items, D14, H23, etc., that are excluded from the

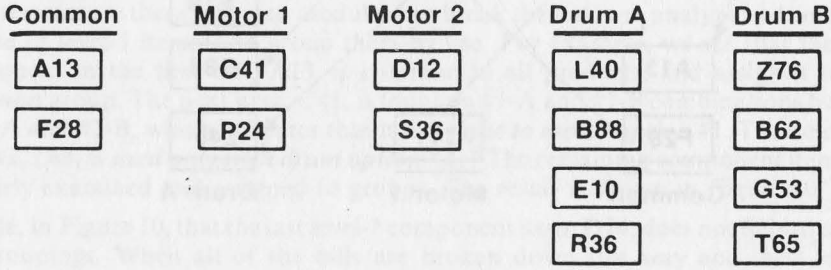

Figure 12.

planning bill cannot simply be abolished. These items will eventually have to be assembled, and the production control system has to be able to place orders for these items, schedule them and requisition their components. These bills must therefore be retained for the purposes just mentioned.

This represents another technique of bill of material structuring: the establishment of ***manufacturing bills,*** or ***M-bills,*** which together constitute the M-bill file. These bills are coded to distinguish them from planning bills, so that the MRP system will, in effect, bypass them. M-bills are not involved in the process of component requirements planning. They are used for purposes of assembly only. M-items are built against the final assembly schedule, usually to customer order (or warehouse order), using the components planned through MRP.

The principle involved here is that in modularizing the bill of material at whatever level, ***end product bills (level-0) can be abolished entirely but not any bills formerly on level-1 or lower.*** These must be segregated in the M-bill file and retained for purposes of ordering, scheduling, costing, etc. Specifying options in Order Entry (or in scheduling a warehouse order) will call out and reconstruct the proper bills for individual end products, but not for lower level assemblies that have been removed from the planning bill file.

In the example we have been using, the total bill of material file would consist of:

1. ***The planning bill file***
   comprising bills shown in Figure 12.
2. ***The M-bill file***
   comprising bills for D14, H23, J39, and N44.

The Production and Inventory Control Handbook* contains an example of bill of material restructuring that illustrates another technique. Namely, ***reassigning*** components from one bill to another. It is in chapter 17, and the reader is referred to the detailed discussion and illustrations contained there. The example used involves an engine, transmission, intake manifold, carburetor and flywheel housing. This technique is really another version of modularizing. The difference is that the items being broken out, like the manifold, are ***not*** being promoted to level-1 status but are reassigned as components of another level-1 item, such as the carburetor.

This will get the right components planned but, because the manifold, for instance, does not ***really*** get assembled with the carburetor, certain new problems will be created. For example, stock requisitions or service parts orders for the carburetor should not call out manifolds, the cost build-up of the carburetor must not include the manifold, etc. Special procedures would have to be established within the system to handle this. Two bills would have to be maintained for the carburetor. One, a planning bill, with the manifold and another one, an M-bill, without it. But in this case, it would not otherwise be necessary to set up two carburetor bills if the illegitimate components were not assigned to it.

This technique of reassigning components is unnecessarily complicated and vulnerable. The straight modularization technique demonstrated on the previous example is cleaner and gets the job done in a simpler fashion. We mentioned earlier that one reason for modularizing is to disentangle option combinations, for purposes of forecasting and master scheduling. In our example of the hoist, this has been accomplished by establishing the modular planning bill shown in Figure 12. The other objective of modularization, segregating common from unique (optional) parts for purposes of inventory minimization, has not been fully met, however.

*Production & Inventory Control Handbook, McGraw-Hill, 1970

In modularizing the bills, we assigned level-1 items to groups, by option. But those items were ***assemblies,*** and they may contain common components. For example, a subassembly that is only used for motor #1 could have some common parts with another subassembly used for motor #2. Requirements for such common parts will be overstated, if they are included in the safety stock for ***both*** options. If we want to get at these common parts, we would have to tear the bills apart even further. In some cases it is desirable to do that, but if this technique is carried to its extreme, we might finally end up with a planning bill that has only piece parts in it and no subassemblies. The ultimate module of the product is really the piece part.

The question is this: When we do modularize, how far down the product structure should we go? What we are really doing when we modularize is determining the right level in the bill of material at which to forecast. Whether we should forecast the subassembly itself or just its components—and that is the question here—depends on ***when*** we need to assemble it.

We have two choices. Either we assemble it as a function of executing the master schedule, through MRP. This means assembling to stock, or ***preassembling,*** before the end product itself is scheduled to be built, which is probably after receipt of a customer order. Or we defer putting this subassembly together until such time when we build the end product. The making of the subassembly then becomes a function of executing the final assembly schedule. The decision between these two alternatives is pretty much dictated by the nature of the product in question and by the nature of the business. Lead times and the economics of subassembly operations will determine, in each case, whether the item should be pre-assembled or whether it can wait until final product assembly.

Let us take the pendant on the hoist as an example. We can wait and assemble the pendant, and ***its*** subassemblies, when we build the final hoist to customer or warehouse order. But, on the other hand, we may want to have the pendants in stock when the order comes in, so as not to have to assemble them one at a time. If this is the case, we would have to leave the respective bills alone, even though some common parts will consequently be tied up in the pendant assemblies. The master schedule would then contain pendant bill numbers rather than their component numbers.

In trying to arrive at the answer to the question we are examining here it is helpful to distinguish between the:

1. Master production schedule
2. Final assembly schedule

The master schedule represents a ***procurement and fabrication schedule.*** The final assembly schedule, created later in time, must stay within the constraints of component availability provided by the master schedule through the MRP system. (These schedules may coincide where the product either contains no options or is small and simple, etc.) Different subassemblies are under the control of these two schedules, and in modularizing bills of material we are, in effect, assigning a given subassembly to either one of these schedules:

1. To the master schedule, by retaining it in the planning bill
2. To the final assembly schedule, by breaking down its bill (i.e., transforming it into an M-bill)

Thus the question of how far down the product structure one should go in modu larizing tends to answer itself when the bill for a particular product is analyzed, and when we look at the nature of the various subassemblies in a particular business environment.

To conclude the discussion of modular bills of material, it may be proper to reflect on the objectives of modularization. Besides the specific objectives brought out earlier, there is a broader, more fundamental reason. And that is to maintain flexibility of production with a minimum investment in materials inventory. We want to offer a wide choice of products and to give maximum service to customers, and at the same time keep component inventories down. Modular bills of material are intended to help us do just that.

PSEUDO-BILLS OF MATERIAL

There is one more problem that is related to the modular bill of material. When the bill is broken down in the process of modularizing, various assemblies are promoted and become end items; i.e., highest-level items with no parent. This tends to create a large number of end items. Because it is the end items that will have to be forecast, and because the master schedule has to be stated in terms of these end items, we could end up with hundreds (or thousands) of end items, too many to work with.

Fortunately, there is a simple solution to this. We certainly want the smallest possible number of things to forecast, and the smallest possible number of end items shown on the master schedule. To accomplish this, we can use the technique of creating "pseudo-bills of material." If we go back to Figure 12, where the newly created end items are grouped by option, there is nothing to stop us from taking any group of such items and creating a pseudo-bill to cover all of them. We have done so in Figure 13, where an artificial parent has been assigned to each group, and a new series of (pseudo) bills has been created.

These new bills, sometimes called ***super-bills*** or ***S-bills***, are an example of ***non-engineering part numbers*** being introduced into a restructured bill of material. An S-number, such as S-101 in Figure 13, identifies an artificial bill of material for an imaginary item that, in reality, will never be built. The only purpose of the S-number is to facilitate planning. With the S-bills set up, when we forecast drum size, for instance, we forecast S-104 and S-105 only. These pseudo-bill numbers will also represent these options in the master schedule. The MRP system will explode the requirements automatically from this point on, using the S-bills in the bill of material file.

A total of 47 S-bills (one for each option plus one for common items including the hook) would cover the original (non-simplified) example of the hoist represented in Figures 7 and 8. The 47 compares with 2,400 end product bills or with several hundred end item (level-1) bills.

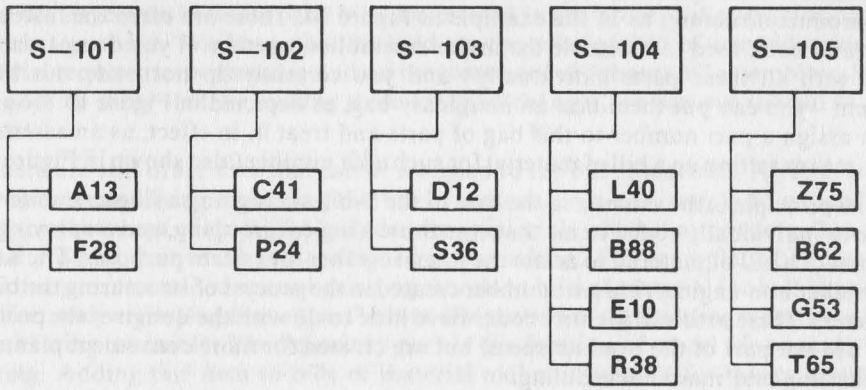

Figure 13.

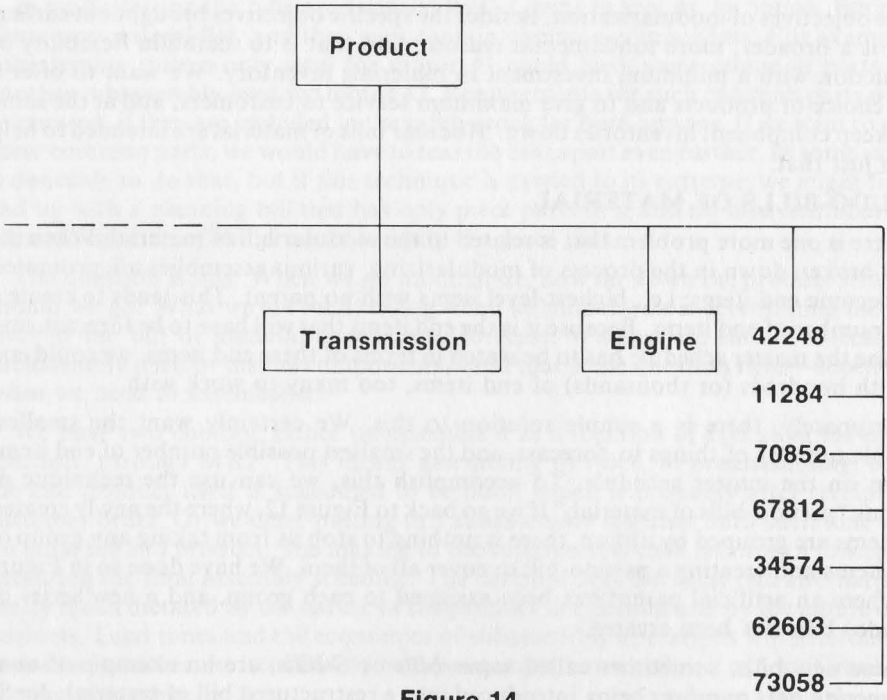

Figure 14.

In this article, the terms "S-bills," "S-number," and others, are being used for lack of standard terms. The terminology in this whole area is unfortunately entirely non-standard, as the subject has been almost totally neglected in literature. One of very few exceptions is the article by Dave Garwood* in which he described the results of restructuring the bills of material at Fisher Controls Co. In his article, the term "partial parts list" (PPL) corresponds to the S-bill, and the term "Item" to an option or option grouping.

Another pseudo-bill term in current use is the "Kit number" or "K-number." This technique is used by some companies that have a lot of small loose parts on level one in the product structure, as in the example in Figure 14. These are often the fasteners, nuts and bolts used to assemble the major assemblies together. If you do not want to deal with all these parts individually—and you certainly do not under an MRP system—you can put them into an imaginary bag, as depicted in Figure 15. You can then assign a part number to this bag of parts and treat it, in effect, as an assembly. This means setting up a bill of material for such a kit number (also shown in Figure 15).

The principle is the same as in the case of the S-bill—assigning a single new identity code to individually coded items that constitute a logical grouping, and employing the format of a bill of material to relate the items together for system purposes. The K-bill is another non-engineering part number created in the process of structuring the bill of material. These artificial identity codes have little to do with the design of the product and are not part of the product specs, but are created for more convenient planning, forecasting and master scheduling.

*"Stop: Before You Use the Bill Processor," by D. Garwood, *Production & Inventory Management*, Second Quarter 1970.

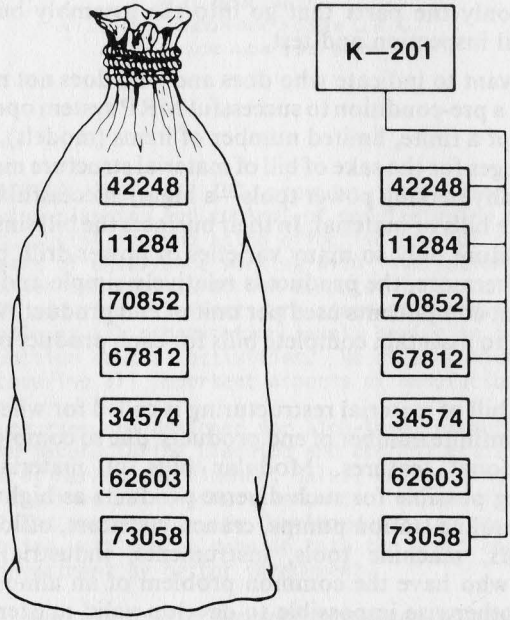

Figure 15.

These newly created bills, along with the M-bills we discussed earlier are sometimes collectively called the ***superstructure.*** The superstructure, once established, must then be maintained along with the rest of the bill of material file. This is a new job, which means that the cost of file maintenance will normally go up.

CONCLUSION

In the previous sections of this article we have reviewed modularization, which does away with end product bills and creates separate planning bills and manufacturing bills. We have seen how artificial bills are created in the process of restructuring and for what purpose. We have also touched on the relationship of item identities to material requirements planning and on the treatment of "phantom" assemblies. All of this goes to show that by making these kinds of changes, we can put the bill to new uses.

There are still other uses that can be assigned to the bill of material. An interesting example of modifying and using the bill of material in a new way is to expand the traditional concept of the bill to include other materials which may not actually a part of the product, but which are consumed in its making. For example, a ball bearing manufacturer has added special grinding wheels to bills of material for ball bearings. In effect, they are saying that a "part" made of a portion of the grinding wheel goes into each bearing assembly. The "quantity per" is the fraction of wheel life to make one bearing. Adding this item to bills of material makes it possible for this company to project requirements for expensive grinding wheels and thus minimize investment in this inventory, as well as to reduce the possibility of a shortage of grinding wheels.

An electrical machinery manufacturer has added electrical specification numbers for power transformers to bills of material. The assembly orders generated from these bills then show not only the parts that go into the assembly but also the proper specifications for final inspection and test.

In conclusion, we want to indicate who does and who does not need to restructure the bill of material, as a pre-condition to successful MRP system operation. Where the product line consists of a finite, limited number of items (models), modularizing the bill, or any other changes for the sake of bill of material structure may be unnecessary. For example, a company making power tools—a highly successful user of MRP—did not have to restructure bills of material. In their business the bill simply is no problem, because they manufacture only so many varieties of power drill, power saw, etc., in large quantities. Furthermore, the product is relatively simple and small, in terms of the number of different components used per unit of end product. With a product line like that, it is feasible to maintain complete bills for each product model and forecast and plan by model.

On the other hand, bill of material restructuring is called for where the product line consists of a virtually infinite number of end products, due to complexity of design and wide choice of optional features. Modular bills of material make material requirements planning possible for such diverse products as highway truck trailers, mining machinery, gasoline station pumps, cranes, elevators, office machinery, farm machinery, computers, machine tools, instruments, industrial tractors, and a multitude of others, who have the common problem of an almost endless product variety that make it otherwise impossible to develop valid master schedules.

The study of how bills of material should be constructed is therefore a vital part of the work of designing and implementing an MRP system. Structuring the bill of material requires some real cooperation from the engineering department, and sometimes this can be a problem. After the bill is restructured, it can no longer "belong" to the engineers exclusively, and that can sometimes be a problem also.

The bill of material can and should be more than just part of product specs. It should also be viewed and used as a ***tool for planning.*** The resistance by some engineering departments to changes in bill of material format, structure, maintenance, etc., cannot really be justified. After all, the engineers create the bill so that, by definition, somebody other than the designer can make the product. The bill of material is, therefore, really made for others in the first place. And it would seem to follow that it should be structured for the ***user's,*** not the designer's, convenience.

An ex-engineer friend of ours put it this way: "When I worked as an engineer, I saw the creation of the bill of material as the ***last step in the process of desing.*** But when I later moved into production and inventory control, I began to see it as a ***first step in the process of planning."***

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